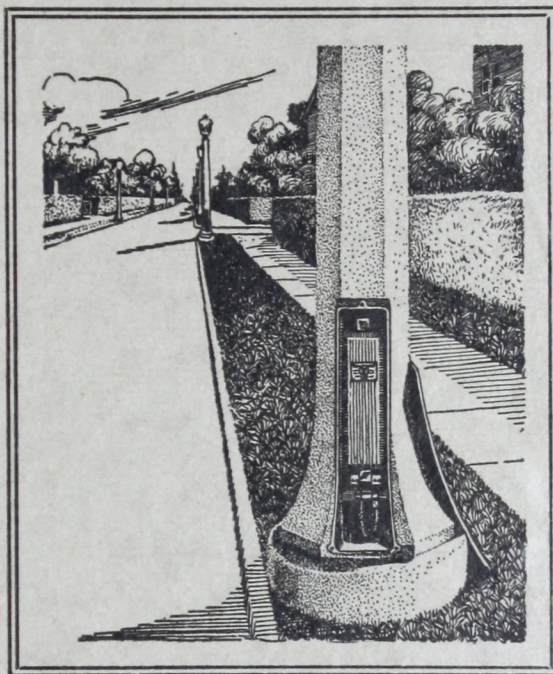


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Resonant Control For Street Lights



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Resonant Control

. for .

Street Lights



Circular 1757-B

Westinghouse Electric & Manufacturing Company
EAST PITTSBURGH PENNSYLVANIA

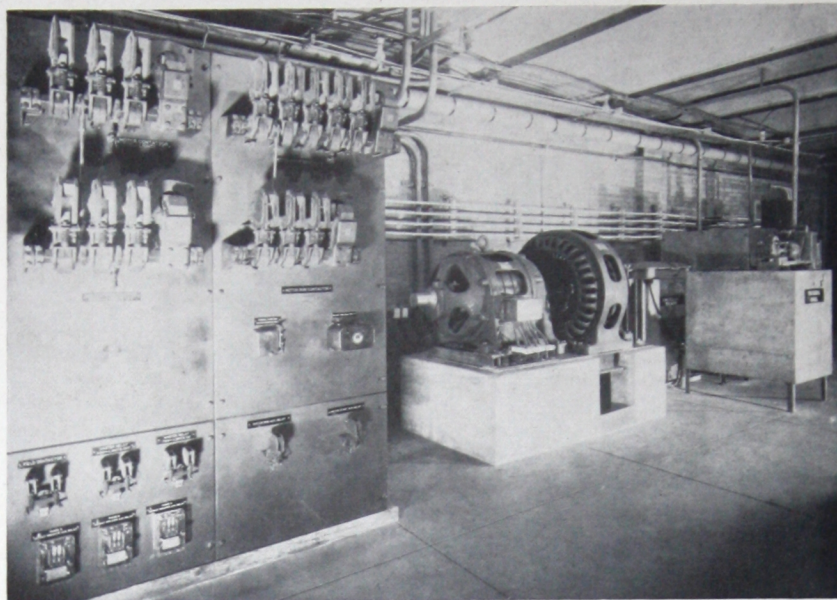


Fig. 1—Resonant Control Installation Showing Switchboard and Motor Generator.

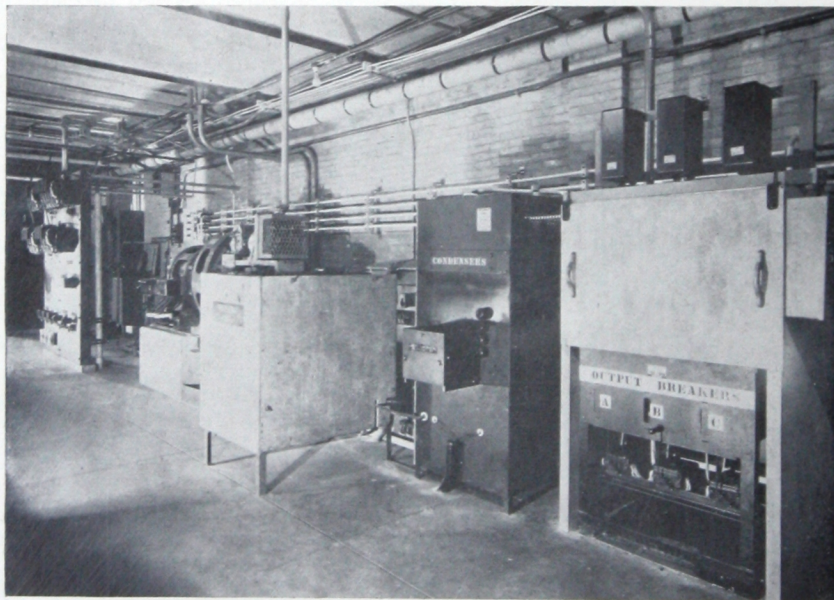


Fig. 2—Resonant Control Installation Showing Tuning Coils, Condensers and Circuit-Breakers.

FOREWORD

The methods for control of street lights have passed through a long period of evolution. In reviewing the progress in this field of development from the time of the lamp-lighter to the present day, it will be found that street lighting control systems have kept pace with the rapid developments in lighting units, standards, transformers and cable.

We now come to another important step in control which makes possible the control of street lights from a central point without the use of pilot circuits. The system, known as Resonant Control, was primarily developed for the control of multiple street lights. However, it also makes possible the control of automatic series constant-current regulators from a central point without the necessity of long control circuits.

The elimination of control circuits is made possible by sending a medium frequency current over the regular lighting and power circuits. It is transmitted to relays located in the base of each lighting standard. In the control of multiple street lighting, the relays control one lamp directly. While with series circuits, the relays operate the remote-control oil switch controlling the primary of the regulator.

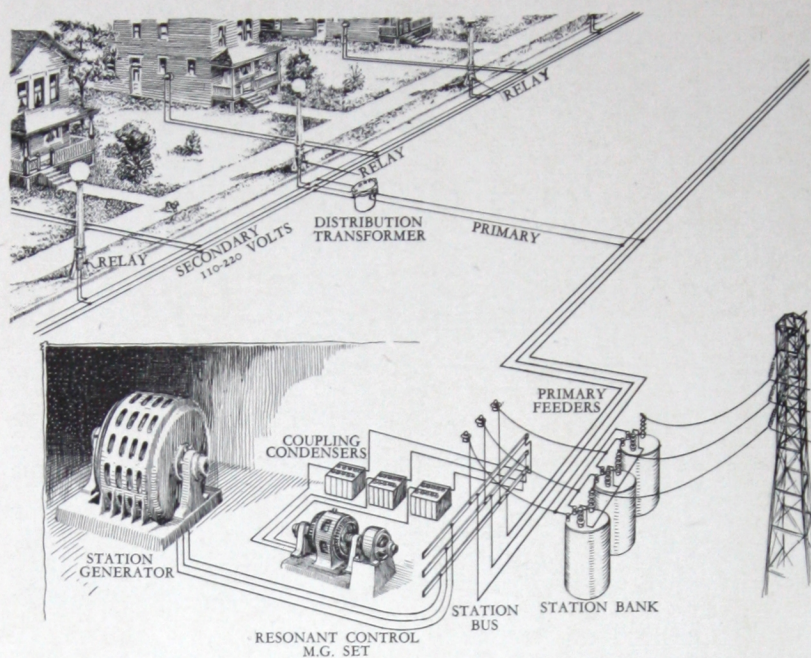


Fig. 3—Pictograph of Resonant Control Exterior Circuits
Three Phases Energized Simultaneously.

Note Simplicity of Street Light and Customer Distribution.

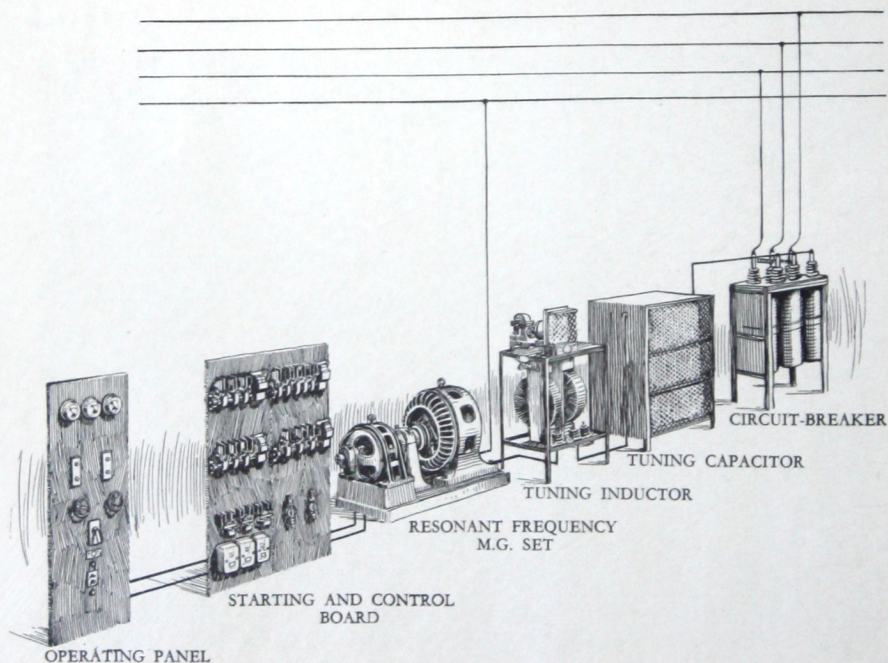


Fig. 4—Pictograph Showing Resonant Control Station Equipment
Three Phases Energized Consecutively.

Westinghouse

Resonant Control for Street Lights



THE rapid development of radio has greatly stimulated interest in the properties of electric circuits. It has led to a clearer, better and much more general understanding of all circuit phenomena and particularly those relating to high frequencies. This knowledge and experience has lately been turned to great practical advantage in providing a solution for the problem of street light control.

The difficulty of turning multiple street lights on and off has been a serious obstacle to the general adoption of the multiple system. This problem has been solved by the use of medium frequency currents. These currents are superimposed on the regular power currents and in no way affect or interfere with the normal operation of the power system.

The general idea of superimposing medium frequency currents on the circuits of a power system was proposed many years ago. It remained unsolved however until the advances in radio gave a clearer understanding of the circuit properties involved. The work was finally undertaken and completed by the Radio Engineering Department of the Westinghouse Electric & Manufacturing Com-

pany at the request of one of the large power companies directly interested in supplying multiple street lights from its existing secondary network. The apparatus developed represents the results of four years of intensive research and experiment in conjunction with one of the largest public utilities in the country. The system as worked out is quite simple. The control units are small in size, rugged in design, and of low cost. The system is believed to be superior to any known existing method for the control of multiple street lights. It is also well adapted to the remote control of series lighting systems fed by pole type regulators. Many difficult problems of remote control and switching may be solved by adopting this system.

General Principle

The basic idea of the control system is to use the existing power conductors as the control circuit. The control currents are transmitted over the lines just like power currents. The frequency of the control currents used is sufficiently higher than the power frequency to make it easy to separate the control currents from the power currents.

Special relays employing tuned circuits are provided at points where control is desired. These relays are connected across the 110-volt mains which feed the individual street light or group of lights. The relays respond only to currents having the particular frequency for which they are tuned. Sufficient energy is fed through the power system to the control relays to operate them by the direct electromagnetic pull of the control currents themselves without the use of vacuum tubes, amplifiers or rectifiers of any kind. This avoids complication and delicacy in the control units and also avoids using parts requiring periodic replacement.

Two control frequencies are used, one to turn the lights on and one to turn them off. This method is preferred because of its directness and simplicity. Where only two or three simple operations are required the use of one frequency for each operation works out better than by using a single frequency with some form of selector. It gives a system of greater simplicity and reliability. It is also more compact and much cheaper.

Method of Feeding Control Currents into the Power System

The control currents are fed into the power system at the substation. A single feeder may be energized alone or all the feeders on a bus may be energized at the same time. Single phases may be energized by switching from feeder to feeder, or the entire bus may be energized by making connection to the bus instead of to individual feeders. The control currents flow along the conductors just as

though the power currents were not present. The frequency of the control currents is selected so as to avoid serious loss in transmission and to permit being efficiently stepped up or down through the existing power transformers. Frequencies of about 500 cycles are used. These frequencies are transmitted with very little loss even through cable systems.

The method of introducing the control currents into the power system is shown in Fig. 5 which is a schematic diagram of a substation bus with a single feeder. The control currents are produced by the generator "G". This is a rotating machine of a standard type driven by a two-speed induction motor or by a single speed induction motor with a two-speed gear shift. The two-speed motor runs at 1200 and 1800 rpm., while the single speed motor runs at 3600 rpm. The latter is a smaller unit, and, since it is for short-period use, the oil immersed gears are not objectionable. The generator produces control frequencies of 480 and 720 cycles at 1200 and 1800 rpm. respectively. The generator is coupled to the feeder by means of a tuned circuit. This tuned circuit consists of suitable condensers, and inductance coils. The condensers are of the oil filled type similar to those ordinarily used for power factor correction. The inductance coils are made of special stranded cable to reduce copper losses to a minimum. A transformer of suitable ratio is interposed between the generator and the tuned circuit so as to adapt the generator to the low impedance circuit which it feeds. The condensers are connected directly to the feeder and serve the double purpose of tuning the generator circuit and of in-

roducing a high impedance to the flow of power frequency current back through the generator.

The current delivered by the generator and tuned circuit to the feeder has two paths in which to flow. Referring again to Fig. 5 it may flow from junction 1 back through the feeder regulator, reactor, station transformer bank to junction 2. It may also flow from 1 out along the feeder through the numerous distributing transformers and their connected load and back to 2. The current divides be-

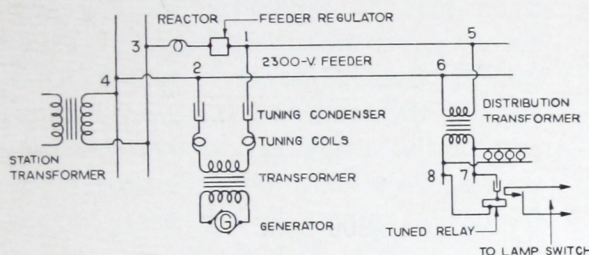


Fig. 5—Schematic Diagram of Substation Bus with Single Feeder

tween these paths inversely as their respective impedances. The two paths in parallel present a combined or resultant impedance to the flow of input current from the generator. The input current multiplied by this resultant impedance gives the value of the control frequency potential superimposed on the power system as measured across the feeder terminals at points 1 and 2. This potential is superimposed on top of the power frequency potential and it acts independently, i.e. as though the power frequency were not present. The value of this potential for a 2300-volt feeder is approximately 100 volts. So far as the control currents are concerned the system can be viewed as though the feeder were energized by a 100-volt generator connected

across points 1 and 2 as shown in Fig. 5. This 100-volt control voltage acts throughout the whole length of the feeder and excites the primary side of all distributing transformers on the feeder. The transformers step this control voltage down, in the same ratio as the power voltages, giving 5 volts on the 110-volt side of each transformer. It is this voltage which is available for the operation of the tuned control relays.

The superimposed potential does not add directly to the power potential but adds vectorially at right angles. Thus 5 volts of control potential adds only .11-volt to the effective system potential. A superimposed potential of 20 volts will only increase the 110-volt secondary potential by 2 volts. The energy required to produce the superimposed control voltage is a very small part of the energy rating of the power system. It may be of interest to note that the control frequency generator runs at 100% power factor and supplies only the power component of the superimposed kv-a.

The existing wires and cables of a power system therefore provide an efficient channel for the transmission of independent control currents for all sorts of purposes. There is no difficulty in transmitting control currents, having sufficient energy to directly operate suitable relays, to all parts of the system.

Resonant Relays

The relays used in this system of control utilize the direct electromagnetic pull of the control current; that is, the control currents are themselves sufficiently strong to move the relay armature on which is

mounted the control contact. This is a great advantage in that it avoids the complication of amplifying tubes, rectifying tubes or delicate relay mechanism.

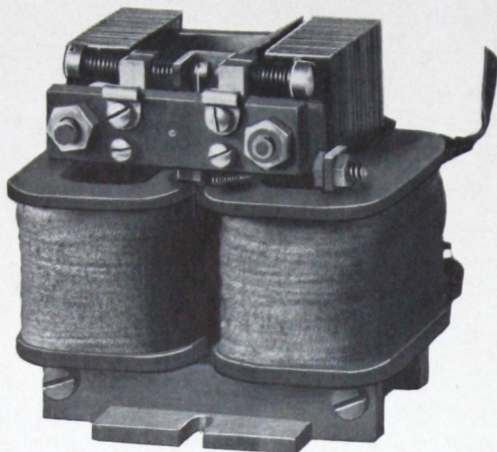


Fig. 6—Resonant Relay Used for Street Light Control

Fig. 6 shows the general appearance of the type of relay used for streetlight control. Fig. 7 is a diagram showing principal features of the relay. It consists of a simple "U" shaped electromagnet acting on a balanced armature. The armature carries the control contact which completes a circuit through a contactor switch in the lamp circuit. The relay contact therefore does not carry the lamp current but only the control current for the contactor switch. The contacts of both the relay and the contactor switch are made of pure silver to assure perfect contact under all service conditions.

The magnet winding of the relay plays a double part. In addition to its normal function in which it plays the part of a simple electromagnet, it furnishes the inductance necessary to tune the relay to the desired control frequency. The relay is connected to the line through a condenser which furnishes the other element

necessary to form a tuned circuit. The condenser also acts as a stopping condenser to prevent the flow of an appreciable amount of power frequency current through the relay. The inductance of the relay is so adjusted that the circuit consisting of the relay and condenser are in series resonance for the frequency on which the relay is required to operate. That is, the reactance of the relay circuit as a whole is zero for its operating frequency. This circuit is connected directly across the 110-volt line as shown at 7 and 8 on Fig. 5. Since the relay is connected across the supply line at all times a small amount of power current will flow through the condenser and relay but this current is much below the operating value. This continuous flow of power frequency current is a leading current,

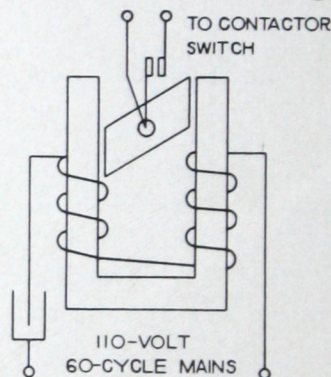


Fig. 7—Diagram Showing Principal Features of Resonant Relay

being almost entirely wattless. This leading current is a benefit to the system in that it helps to correct the power factor.

Since the reactance of the relay circuit is zero for the operating frequency, the current flowing through it is governed by Ohm's law, thus:

$$I = \frac{E}{R}$$

where E is the value of the control frequency voltage impressed across the relay circuit, R is the effective resistance of the relay circuit, and I is the current flowing through the relay winding. It is obvious that the lower the effective resistance of the relay circuit, the more energy will be available to operate the relay. This resistance is therefore purposely kept low so as to draw ample control frequency energy from the power system.

It might be noted here that the principal difficulty encountered in the development of this system of control was in keeping the losses in the relay circuits sufficiently low. By careful selection of materials and proper proportion of the magnetic circuit, these losses were cut down well under the values necessary

for successful commercial operation. It was the successful development of these low-loss relays which made it possible to draw sufficient control frequency energy from the power system to positively operate a pair of contacts by the direct electromagnetic pull of the control current itself.

Resonant Control Unit

Figs. 8 and 9 show the appearance of the complete street light control unit. Either a metal or glass cover can be used. The equipment is assembled in a waterproof case and is of such dimensions as to permit its being mounted in the base of the majority of ornamental street light posts. See front cover. Each control

unit consists of two tuned relays with the necessary condensers and a suitable contactor switch to turn the lamps on or off.

A schematic diagram of the elements in the control unit is shown in Fig. 10. The tuned relays are shown as 1 and 3 on the diagram. The switch or contactor in the lamp circuit is of the toggle-type; that is, it is pulled over a center and will remain permanently open or closed as the case may be. The operating coils of this toggle switch are indicated at 2 and 4.

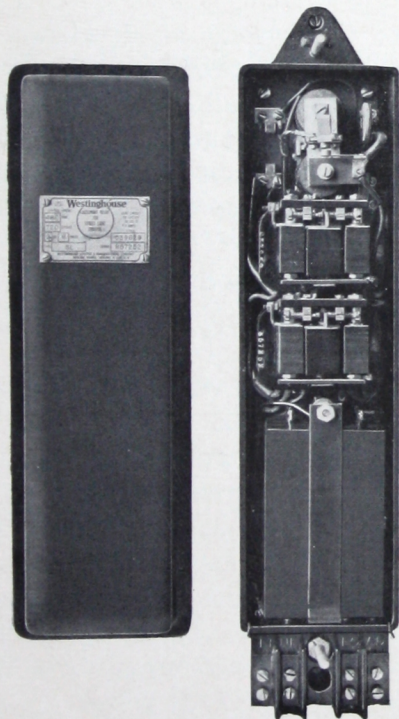


Fig. 8—Street Light Control Unit With Metal Cover, Cover Removed

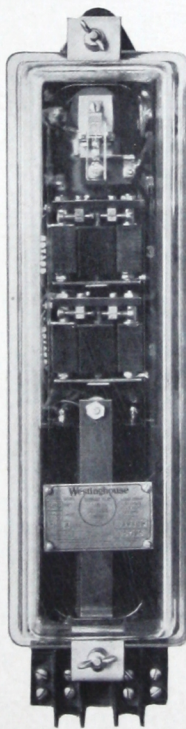


Fig. 9—Street Light Control Unit with Glass Cover

Operation

When it is desired to turn on the street lights the control frequency generator in the substation is brought up to speed and run at the "On" frequency. The generator circuit is closed momentarily on the feeder carrying the street lights being

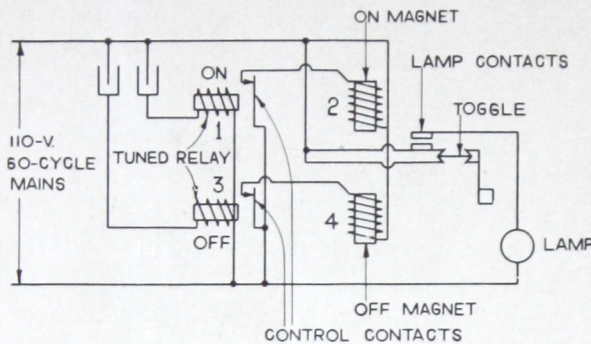


Fig. 10—Schematic Diagram of Elements Used in Control Unit

controlled. This sends the "On" frequency to all parts of the feeder and all its connected apparatus. All relays tuned to the "On" frequency immediately respond and close their control contacts. Then relay 1, Fig. 10, is pulled up, thus energizing the operating magnet 2 of the toggle switch, closing the switch and lighting the lamp or lamps. The generator at the substation is then disconnected. The "On" relays drop back to the open circuit position but the contactor switch remains closed owing to the toggle. The lights remain "On".

When it is desired to turn the lights off the control generator at the substation is brought up to speed at the "Off" frequency and closed momentarily on the feeder. This energizes the "Off" relays all over the system. These relays in turn energize the operating magnets of the toggle switches and pull the switches

to the open position. The control generator is then disconnected, the "Off" relays drop back to the open position but the toggle switches remain open and the lamps remain "Off".

In the design of the street light control unit particular attention was given to the jar and vibration to which it is subjected when mounted in the base of the lamp post due to street traffic. The control relays are immune to vibration from street traffic owing to the use of the balanced armature and to the ample magnetic pull which the relay develops. The toggle switch is also immune to street traffic vibration.

Application to Series System Using Constant-Current Regulators

While the system as developed was worked out with special attention to the requirements for multiple street lights, it is also well adapted to the series systems fed from automatic-station type, manhole type and pole-type regulators. In addition to advantages in the concentrated lighting areas, resonant control makes possible the central control of series street lighting circuits for rural districts, over a wide area without the necessity of long pilot circuits.

The method of applying Westinghouse control to series systems fed from constant potential feeders through a pole-type regulator is indicated in Fig. 11. The pole-type regulator is connected to the 2300-volt power feeder by a remote control oil switch which may be a Westinghouse type RCOC switch. This switch is controlled by a standard resonant control unit energized from the

2300-volt feeder, through the medium of a step-down potential transformer. This transformer is necessary to provide the 110-volt source for operating the street light control unit and also for supplying the control current for the oil switch. If a 110-220-volt distributing circuit is nearby, the potential transformer may be omitted and the control frequency and operating current supplied from it.

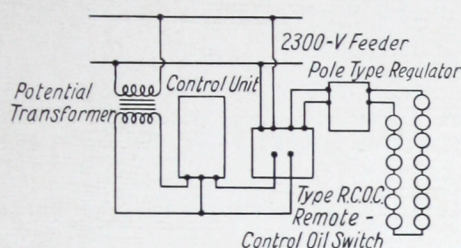


Fig. 11—Diagram of Westinghouse Control for Series System

Miscellaneous Applications

Resonant control as developed for street lighting has a wide application to many other control problems. The Westinghouse Medium Frequency supervisory control system utilizes the principles and apparatus of resonant control for the remote control of power apparatus. Resonant control can also be used for the control of sign lighting and for any

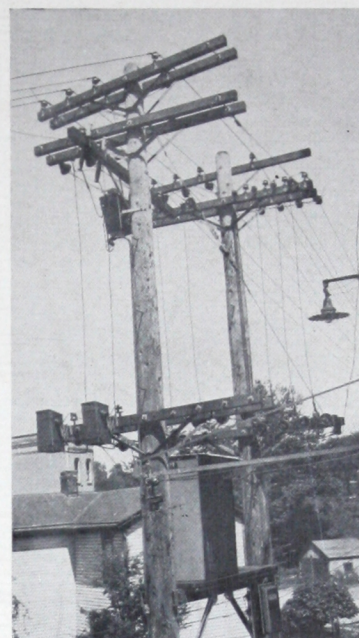


Fig 12—Application of Resonant Control to Series Lighting Circuits

application ordinarily requiring time switches. Remote metering using the transmission lines for line wires may also be accomplished. The two-rate method of metering is also possible. When the hours of peak load arrive, a high-rate meter may be substituted for a low-rate meter and when the peak is passed the low-rate meter can be returned to the circuit.

Questionnaire

The rating of the equipment used for superimposing control frequencies on the distribution circuits is proportional to the rating of the system that the equipment has to energize, and it is to a great extent independent of the number of resonant relays to be controlled. It is therefore essential that the following questions be answered in detail in order that our engineers may choose adequate equipment.

Station Data

1. Do you prefer consecutive or simultaneous energizing of phases? State number of phases.
Note: Consecutive energizing requires less equipment.
2. Do you prefer consecutive or simultaneous energizing of feeders? State number of feeders and rating.
Note: Where single feeders are energized the generating equipment is proportional to the rating of the feeder, but more wires and switching equipment are required for the station.
3. Is the portion of the system which is to be controlled fed from more than one source or more than one direction?

RESONANT CONTROL FOR STREET LIGHTS

QUESTIONNAIRE—Continued

STATION DATA—Continued

4. Are these sources generators or transformers or both?
5. Give rating, voltage and percent impedance of each generator. Are they delta or star connected?
6. Give rating, voltage and percent impedance of each transformer. Are they delta or star connected?
7. Give diagram showing circuit arrangement of each station which feeds the portion of the system to be controlled, showing generators, transformers, feeder reactors, feeder regulators and busses. Is 110 volts d-c. available for generator field?

Transmission or Distribution System

8. Give diagram showing portion of system to be controlled including branches for which control is not contemplated.
9. Give cable lengths, sizes and cross section construction of cable portion of system.
10. Give lengths, sizes and spacing of over-head portion of system. Note 1—This information should be given in detail for transmission circuits, but for distribution feeders from substations a typical feeder may be given. Note 2—If only a portion of the system is to be energized, do you object to the insertion of reactors in the line to limit the control current to this portion.
11. Give range in rating and average rating of distribution transformers with type of connection and approximate percent of impedance.
12. Describe the low tension distribution feeder lay-out.

Type of Control

13. Do you desire control of multiple or series lighting, or other type of load.
14. If multiple, give typical layout of lighting standards with respect to secondary distribution feeders. Note, if lighting standards are adjacent to secondary distribution feeders, it is preferable to use one relay to each standard.
15. Give size and number of lamps per lighting standard. Is one side of the lamp permanently connected to the live side or to the ground side of the line?
16. If series lighting, give typical lay-out of primary and secondary distribution feeders with respect to series lighting feeders.
17. Can secondary distribution circuits be used for control or must potential transformers be provided?
18. Are constant current regulating transformers to be included in the estimate or are these in the possession of the customer?
19. Give rating and voltage and method of connection to primary distribution circuits.
20. Are the oil switches to be included in the estimate or are these in the possession of the customer?
21. Give rating, voltage and type of connection desired for oil switches.
22. Is lightning protection for the oil switches and constant current regulators to be included in the estimate? If so, give type of protection desired.
23. If for sign lighting, store window lighting or off-peak loads, such as hot water heating, give complete description of type of control service desired.

General

24. Give estimate of proportion of power and lighting load at the times for using resonant control.
25. Give prediction of growth of stations and circuits.

Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

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WESTINGHOUSE ELECTRIC INTERNATIONAL CO.

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